

Go through quick timeline from philosophers to Rutherford

BUT atomic structure must go into classic non newtonian physics of quantum theory

7.1 Electromagnetic Radiation - so many uses occurrences
 Visible light - X Rays, microwaves
 Radio

They are waves w/ primary characteristics

$$c = \lambda \nu$$

c Speed $3.00 \times 10^8 \frac{m}{s}$
 λ wavelength m
 ν frequency $\frac{1}{s}$ cycles $\frac{1}{s}$ or Hz
 $\lambda \propto \frac{1}{\nu}$

EM Rad primarily transfers E

↳ heat from sun

↳ microwave heat food

7.2 Nature of matter

Interesting end of 19th Century Physicists felt since
their theories explained everything. Students were discouraged
from being physics majors b/c everything was explained.

Matter \rightarrow particles had mass could be localized
Light \rightarrow waves had no mass couldn't be discrete positions

That was Before 1900

In 1900 Max Planck

\hookrightarrow heat metals they glow. Thought matter could
absorb emit energy in any quantity. However
Planck said this was untrue.

He postulated Energy only lost or gained in whole multiples
of the quantity $h\nu$ \nwarrow h is Planck's constant $6.62 \times 10^{-34} \text{ J}\cdot\text{s}$

$$E = h\nu \quad \text{or} \quad \Delta E = n h \nu$$

\uparrow
integer 1, 2, 3

Show

Planck said E is ^{lost by matter} quantized and can only occur
in discrete units of size $h\nu$ ^{not continuous}
 \hookrightarrow E is like matter! a system can
transfer E in whole quanta

Next Einstein Expanded this w/ Photoelectric Effect

②

↳ Einstein said EM Rad ~~was~~ can be viewed like a stream of particles \rightarrow photons

$$E_{\text{photon}} = h\nu = \frac{hc}{\lambda}$$

Photoelectric effect - hit metal w/ light gives off e^-

Major pts

1. No e^- are emitted by metal hit w/ light below specific ν_0

2. light w/ freq below ν_0 no emitted e^- {Regardless of intensity}

3. light w/ freq above ν_0 # of e^- \uparrow w/ intensity of light (# more intensity, more photons, more e^-)

Assume

EM is quantized

ν_0 is min E

to remove e^-

$$E_0 = h\nu_0$$

$\nu_0 > \nu$ no emission

$\nu_0 < \nu$ e^- emission

4. light w/ freq above ν_0 the KE of the emitted e^- increases linearly w/ freq of light extra E made e^- go faster (excess E of threshold E given to e^- as KE)

$$KE_{\text{elect.}} = \frac{1}{2}mv^2 = h\nu - h\nu_0$$

Data of Relativity showed E has mass!

$$\boxed{E = mc^2} \rightarrow m = \frac{E}{c^2} \quad \text{can use this to calculate mass of a photon w/ a given}$$

$$E = \frac{hc}{\lambda} \quad m = \frac{\frac{hc}{\lambda}}{c^2} = \frac{h}{\lambda c}$$

So $\boxed{m = \frac{h}{\lambda c}}$ so photons have relativistic mass!

Summary of Planck + Einstein

E is quantized it comes in discrete units

EM Rad has dual nature - particle/wave props

1923 de Broglie showed matter exhibited wave props

de Broglie Eqn since c is velocity

$$m = \frac{h}{\lambda v} \Rightarrow \boxed{\lambda = \frac{h}{mv}} \quad \text{de Broglie Eqn}$$

calc λ for a particle

$$h = 6.62 \times 10^{-34} \frac{\text{J}}{\text{s}} \text{ or } \frac{\text{kg} \cdot \text{m}^2}{\text{s}}$$

$$1 \text{ J} = \text{kg} \cdot \text{m}^2 / \text{s}^2$$

Ex Prob 7.3

λ for e^- is same order for spacing b/w atoms impl

small λ means we can test de Broglie's Eqn
via diffraction

show figure.

See w/ CD - color reflects back as Rainbow
B/c not all light reflected the
same way.

Ridges and grooves can produce diffraction
So can a crystal. B/c regular arrang
of ions

only waves give diffraction.

1927 C J Davisson L H Germer diffracted e^- through Nickel
works when λ is same distance as b/w rows of ~~xtal~~ xtal .

Can't test w/ large matter.

so matter like E!

p284 top P great summary

all matter exhibits particulate + wave
props.

Big matter \rightarrow particulate — IM matter — Both

little matter \rightarrow wave

7.3 H spectrum - Experiment that lead to x time of atom

Show fig 7.3 for How BL spec works

In tube H_2 absorbs and $H-H$ bonds Break
then atoms are excited and e^- jump to higher levels e^- fall
light is emitted.

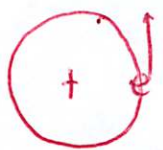
Continuous spectrum \rightarrow white light shone through prism

line spectrum - only a few lines b/c only a few discrete E^-
so the atoms quantized

If any E were all light would be seen.

7.4 Bohr Model 1913

$\hookrightarrow e^-$ moves around the nucleus only in certain orbits



e^- wanted to go in straight line
but stayed circular b/c of pull of e^-

Bohr Eqn to show E levels available to e^- in H atom

4

$$E = -2.178 \times 10^{-18} \text{ J} \left(\frac{Z^2}{n^2} \right) \quad \begin{array}{l} Z - \text{nuclear charge} \\ n - \text{integer of orbit} \end{array}$$

(-) B/c smaller E than $n=80$

We can calculate the E given off when e^- falls from 6th to 1st

$$n=6 \quad E = -2.178 \times 10^{-18} \text{ J} \left(\frac{1^2}{6^2} \right) = -6.050 \times 10^{-20} \text{ J} \quad \boxed{Z=1}^{\text{H}}$$

$$n=1 \quad E = -2.178 \times 10^{-18} \text{ J} \left(\frac{1^2}{1^2} \right) = -2.178 \times 10^{-18} \text{ J}$$

↑ more (-) so more stable

$$\Delta E = E_f - E_i = -2.178 \times 10^{-18} \text{ J} - (-6.050 \times 10^{-20} \text{ J}) :$$

$$\boxed{-2.177 \times 10^{-18} \text{ J}}$$

↑
Neg so E lost

Can calc λ by $\Delta E = h \left(\frac{c}{\lambda} \right)$ or $\lambda = \frac{hc}{\Delta E}$

$$\lambda = \frac{(6.62 \times 10^{-34} \text{ J.s})(3.00 \times 10^8 \text{ m/s})}{2.177 \times 10^{-18} \text{ J}}$$

$$= 9.38 \times 10^{-8} \text{ m} = 93.8 \text{ nm} \leftarrow \text{UV}$$

2 Major Pts of Bohr model

1. The model correctly fits quantized levels of H atom
2. As e^- b/c more tightly Bound it E is more $-$ (more stable)

final Bohr Eqn

$$\Delta E = E_{\text{final}} - E_{\text{initial}}$$

$$= E_{n_{\text{fin}}} - E_{n_{\text{init}}}$$

$$= - (2.178 \times 10^{-18} \text{ J}) \left(\frac{1}{n_f^2} \right) - \left(-2.178 \times 10^{-18} \text{ J} \left(\frac{1}{n_i^2} \right) \right)$$

$$= -2.178 \times 10^{-18} \text{ J} \left(\frac{1}{n_f^2} - \frac{1}{n_i^2} \right) \quad \text{sample 0287}$$

Bohr's model only good for H!

7.5 Quantum Model

Three ~~the~~ forefront scientists Heisenberg, Schrodinger, de Broglie

de Broglie opened the door w/ matter acting like a wave

Schrodinger ran w/ it.

↳ e^- acted like a standing wave

only certain allowed wavelengths in an orbit.

↳ which is why atom quantized

Schrodinger developed wave Eqn

$$\hat{H} \psi = E \psi$$

↑
wave function

total E of atom

↳ set of mathematical functions called operator

when solved many variations/solutions these solutions are orbitals

orbital not orbit - not circular we don't know

how it moves in this space. we just know it's there!

Ψ is meaningless but Ψ^2 give Probability, of where e^- is. That's what orbitals are areas of high chance of finding an e^- .

Relative Probs

$$\frac{(\Psi(x_1, y_1, z_1))^2}{(\Psi(x_2, y_2, z_2))^2} = \frac{N_1}{N_2} \quad \text{Ratio}$$

100 : 1 for example

You have no clue when in N_1 or N_2 but much more likely to be in N_1 than N_2 consistent w/ uncertainty principle.

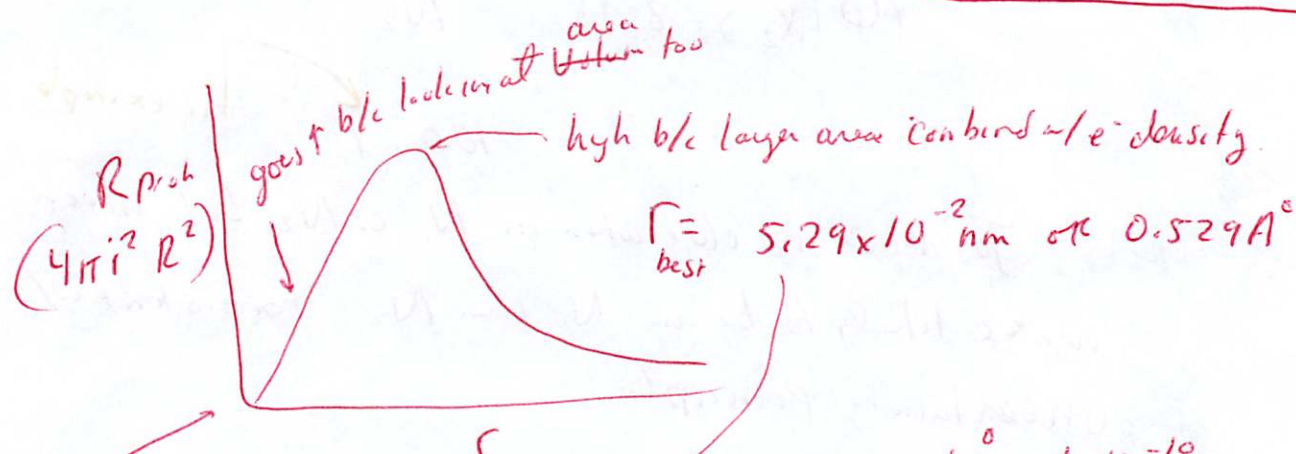
Probability distribution - Ψ^2 @ fig 7.11a & b (e⁻ density map)
Shows where best chance of finding e^- .

Think of e^- as little light. It is always flashing + moving in time give that pattern also shown in Fig 7.11b

Probability Distribution

also want to look @ knowing the total prob of finding the e^- in the H atom @ a particular distance from nucleus

When Fig 12a total Prob of finding e^- in spherical shell is plotted vs. dist we get Radial prob distribution



Better way to depict where e^- is

$$1 \text{ \AA} = 1 \times 10^{-10} \text{ m}$$

exact Radius of innermost Bohr orbit!

Size of orbital is ∞ but depicted as 90% of e^- density.

7.6 Quantum #s

Solving Schrodinger's Eqn we get many orbitals that satisfy it
 These are characterized by quantum #s

principal Q# (n) has values 1, 2, 3, ...
 (energy level)

as $n \uparrow$ orbital size \uparrow and e^- spends more time
 away from nucleus

angular momentum Q# (l) $l = 0 \rightarrow n-1$

\hookrightarrow shape of orbital

$l = 0$ called s etc.

magnetic Q# (m_l) has values b/w $-l$ to $+l$ incl. 0

\hookrightarrow Relates orbital in space to one another.

Ex when $n = 2$

$l = p$

$m_l \quad -1 \quad 0 \quad +1$

\uparrow
 3 suborbitals

7.7 Orbital Shapes + E

Fig 7.13 s-orbitals have nodes for s $n-1 = 4$ nodes

7.14 p-orbitals

(-) (+) values are math signs like a sine wave has a sign

7.15 p's grow larger just like s's do
as ~~s~~ grow $n \uparrow$

7.16 d-orbitals

7.8 Electron Spin + Pauli Exclusion Prin

4 Q# - spectral data indicates that e^- has a magnetic moment w/ 2 orientations
so they figured it was spinning

m_s - spin Q# $+\frac{1}{2}$ or $-\frac{1}{2}$

Important b/c Pauli exclusion Principle - No 2 e^- have same 4 Q's

holds
an ORBITAL ~~holds~~ 2 Q#'s and they spin opposite

7.9 Polyelectronic atoms

a lot of assumptions

When $2e^-$ + one put into Schrodinger Eqn can't be solved exactly B/c

~~e^- attracts nucleus~~
 e^- repel one another & so eqn can't be totally solved - e^- correlation problem

To combat this say e^- is moving in a field of charge that is net result of nuclear attraction + avg repulsion of other e^-

In Na - $11e^-$

The outer most e^- is attracted to nucleus but e^- is repelled by other $10e^-$. So the effective nuclear charge is shielded and that outer most e^- is not held as tight.

So the orbitals for polyelectronic orbitals are H-like but have slightly different E 's B/c of attraction + shielding

Big Difference H orbitals are degenerate others are Not

$$E_{3s} = E_{3p} = E_{3d}$$

↳ n defines E

Not true $E_{3s} < E_{3p} < E_{3d}$ for others.

e^- prefer order s, p, d, f

why Penetration effect

Fig 7.20 the ~~hump means~~ s orbital spends

more time farther away from nucleus than $2p$

But hump means it spends a small but significant amount of time near nucleus.

Penetration effect causes e^- to be attracted more to nucleus

7.10 The Periodic Table

↳ Made to show patterns observed in chemical props of elements

History

Dobereiner - 1st to group elements w/ similar props

Newlands - arrange in octaves b/c of 8 element repeating pattern

Present Table - Mendeleev - Grouped elements w/ similar props & atomic mass

↳ he predicted unknown elements props
predicted Ge, Sc, Ga Table 7.3

he also corrected atomic masses based on location

Current table arranged by atomic [#] mass

7.11 Filling orbitals

Aufbau Principle - ^{orbitals from} e^- added to lowest to highest E

Hund's Rule - 1 e^- in each space B/f doubling

Valence e^- in outermost principle E level

Core e^- in inner shell

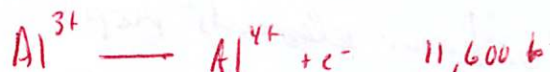
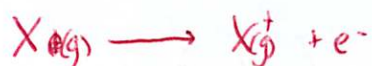
Go over filling order
via periodic table

Counting Periodic table groups

1A - 8A main group Elements \rightarrow Based on val e^-

7.12 Periodic Trends

Ionization E - E req'd to remove an e^- from a gaseous atom or ion



Why increase, b/c 2nd e^- removed from ion. The \uparrow + charge binds e^- more firmly so more E req'd to remove it.

also 1st e^- removed from higher E orbital

When going from 3rd \rightarrow 4th get removal of core e^- which are bound more tightly

Trends in IE $IE \uparrow$ across a period

e^- in same E level do not shield the increasing nuclear charge, so the e^- are more strongly bonded. to moving across table

Stronger Effective Nuclear Charge $Z_{eff} = Z - \# \text{ of Shielding } e^-$

Across a group $IE \downarrow$

B/c as $n \uparrow$ the orbital size \uparrow and the e^- B/c easier to remove

So farther away from nucleus decreases Z_{eff} .

Exceptions - Gr 2A \rightarrow 3A s-orbitals shield p-orbitals
5A \rightarrow 6A e^- Repulsion from doubly filled orbital

Electron Affinity



discrepancy b/c some books use + values b/c E released
our book use (-) values B/OE

Fig 7.32 only atoms that form stable ~~(-)~~ anions shown

Some are more (-)

Trend $L \rightarrow R$ e^- A more (-) Several exceptions

Exceptions depend on Changes in e^- repulsion w/ respect to e^- config

$N \rightarrow C$

N $2s^2 2p^3 \rightarrow 2p^4$ e^- doubling a orbital
So more $(+)$ Repulsion causing N to be unstable

In C $2p^2 \rightarrow 2p^3$ No extra $(+)$ Repulsion

O^- is stable though - more nuclear charge than N
so it can overcome repulsion

Down group e^- A more + B/c ^{added} farther away from nucleus
so less nuclear attraction on ~~by~~ incoming e^-

Table 7.7 low in F_2 B/c 2p orbitals are
smaller than the rest so more e^-
repulsion.

Atomic Radius $\rightarrow \frac{1}{2}$ distance b/w nuclei of 2 adjacent atoms

Sometimes covalent nuclei b/c atoms are bonded together

* probably not real B/c of uncertainty where atom ends

Nonmetals Not diatomic \rightarrow determined from compounds

Metals \rightarrow from pure metal solids

\downarrow
off B/c interpenetration
of atomic e^- clouds

AR across periods \rightarrow AR \downarrow increasing effective nuclear charge

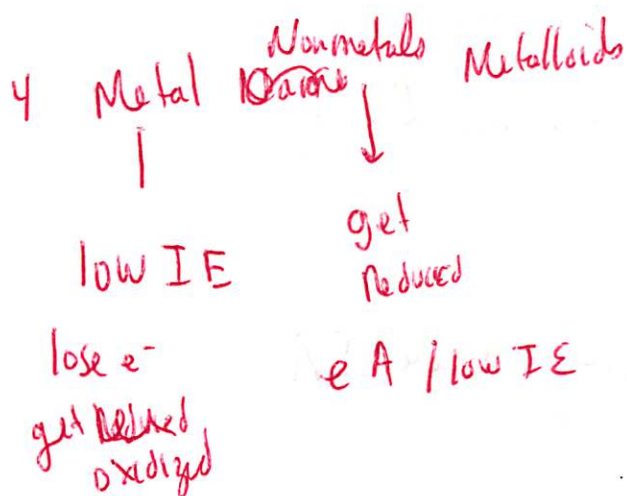
AR \uparrow down group b/c increasing # of principle Q # or E-levels
also orbital sizes increase down a group

Group Properties

1. Val e^- #

2. e^- config

3. Group Names



Alkali Metals

H not included (nonmetal)
So small doesn't lose e^- easily

Use IE to determine Reducing agent ability

in lab Rxns $Cs > Rb > K > Na > Li$

In aqueous $Li > K > Na$

different b/c hydration energy

Li hydration E higher so $Li^+(aq)$ more stable
(more exo)

Why more stable?

B/c charge Density Li^+ has a greater charge

D B/c its smaller and has same charge

So H_2O polar attraction is stronger

But in H_2O $\text{Li} < \text{Na} < \text{K}$ ^{order of Reactivity} exothermic Rxns

B/c melting point

$\text{Na} + \text{K}$ melt giving more SA